The broad nuchal collar of orange of *N. cornutus* is altogether wanting, and there is no difference between the colour of this part of the back.

We observe that the brilliant blue of the primaries of *N. cornutus* is much dimmer in *N. uvæensis*; but this may result from our specimens being caged birds, and consequently not in such perfect plumage. In size and shape the two species are identical.

5. On the Colour of Feathers as affected by their Structure. By Dr. Hans Gadow.

[Received May 2, 1882.]

(Plates XXVII. & XXVIII.)

The colours which we perceive in the things surrounding us may result from various sources, according to which they may be divided into two classes.

The FIRST CLASS consists of so-called objective, chemical, or absorption colours. Such colours do not change or vary under any position of the light or eye; they receive their colour always from a colouring-matter. This may exist in the form of a solution or as pigment. Animal objective colours are mostly due to pigment.

The SECOND CLASS has been variously described as subjective, physical, or structural colours. They are the result of reflected or broken light. This may take place in various ways:—

1. *Total reflection of light*, e.g. the gloss on a polished surface.
2. The light may be broken infinitely often and be totally reflected. The result of this is *white*.
3. *Diffraction* by a prism.
4. *Interference of colours*. By this theory are explained the colours of extremely thin transparent plates, and those which are produced by a system of narrow ridges, *e.g.* iridescence of mother-of-pearl, the blue-heat stage of steel, and the colour of soap-bubbles.

As I have not, in this communication, entered into any general history of the colours of birds' feathers, but have confined myself to the effects of structure, it appears unnecessary to give any detailed critical account of the work of my predecessors, which should only make part of an elaborate and complete essay. The titles of the more important papers, however, are given in the footnote[1].

[1] B. Altum, "Ueber die Farben der Vogelfedern im Allgemeinen, und über das Schillern insbesondere," Naumannia, 1854, p. 293.

B. Altum, "Ueber den Bau der Federn als Grund ihre Färbung," Journ. f. Orn. 1854, pp. xix–xxxv.

A. Bogdanow, "Note sur le pigment des plumes des Oiseaux," Bullet. de la Soc. d. Naturalistes de Moscou, 1856, p. 458.

V. Fatio, "Des divers modifications dans les formes et la coloration des plumes," Mém. Soc. phys. hist. nat. Genève, xviii. (1866), p. 249, plates.

K. W. Krukenberg, 'Vergleich. physiolog. Studien,' ser. 1. pt. v., ser. 2. pt. i. [See also a further contribution (ser. 2. pt. ii.) which has only come into my hands as the revise is leaving them.—H. G., *July 25th.*]

Application of the Laws of Colours to Feathers.

I. Pigment-colours. The simplest case. It has long been a matter of discussion whether or not pigment exists in feathers on account of its never having been successfully extracted. Recently, however, various pigments have been discovered. What we know at present about pigment in feathers is almost entirely the result of the investigations of Bogdanow and Krukenberg.

Pigment may produce the following colours:—

Black, resulting from the presence of *zoomelanin*, a colouring-matter which is probably identical with the melanin of the Chorioidea. This is the pigment most universally found in the animal kingdom, and almost every "black" feather owes its colour to this pigment.

Brown. *Zooxanthin*, found in brown feathers. A mixture of this and the former pigment would of course give black-brown.

Red. The best studied feather-pigment is the *turacin* in the red quills of the Musophagidæ. This very peculiar stuff has hitherto only been found in the Touracous.

Another red pigment is the *zooerythrin*; first extracted by Bogdanow from *Calurus auriceps*, and, as a pinkish matter, from *Cotinga cærulea*. The same matter produces the red in the wattle round the eye of the Black Cock (hence called by Wurm, its discoverer, *tetraonerythrin*). Zooerythrin has been found in very different birds, which, like *Phœnicopterus*, *Cardinalis*, *Ibis*, and *Cacatua*, have more or less red in their plumage; it is therefore very probable that red is generally produced by this pigment.

Allied to the zooerythrin is the *zoorubin*, a red-brown matter in the feathers of *Cicinnurus regius*.

Zoofulvin is a yellow to greenish-yellow pigment.

Turacoverdin is found in the green feathers of the Touracous. In other green feathers no green pigment has hitherto been found, and the same applies to blue and violet.

We may be almost certain that, wherever we have feathers with the various shades of black, brown, red, and yellow, if these feathers do not change their colour in different positions of the eye, their colour is merely due to a pigment. But there may be complication ;. if, for instance, the deeper strata contain a black, and the upper ones superimposed red pigment, the whole will appear dark red. Or if we take red with a superimposed yellow layer, the result will be orange. The richness of colours will often entirely depend on the amount of pigment, *e. g.* grey.

II. *By* diffraction *and* reflection we can explain the following phenomena in feathers :—

1. *White*. There is no white pigment or white objective colour in natural objects ; and wherever we have a white object, its colour is due to there being an innumerable number of interstices between its molecules, or air-cells in its substance. The whole substance of a white feather, the ceratinine, is colourless, but its texture forms a fine network.

2. *Simple reflection of light*. The *gloss* of feathers, independent of

the colour itself, is the result of their surface being smooth and polished: if the surface is rough, the colours given to the feather by pigment appear more or less dull; but if polished, they will appear with a more or less strong gloss, and they will look much more saturated, *e.g.* brilliant red. The polished surface is produced by the horny substance of the feathers.

3. *Interference of colours* and *colour of thin plates*. The thin plates are represented by the extremely thin laminæ of the radii, or by a thin coating of the transparent ceratinine. These parts appear with a certain colour simply because they are thin; but instances of this are very rare, although the planes of the barbules are certainly thin enough to allow the application of colours of thin plates. In *Galbula tombacea*, for instance, the thickness of such a barbule-plane, where it contained only little or no pigment, was under the microscope certainly *less* than 0·1 of one smallest division of the micrometer. The index of actual value for one division, with the power applied, was 0·0063, thus giving an actual value less than 0·0006 mm. The so called iridescence of feathers might be thus explained. An underlying pigment complicates the problem a little. A smooth, glossy surface may likewise be produced by a fine film of oil on the surface of the feathers, *e.g.* in water-birds.

Application of the Theory of Colours which are produced by a system of narrow ridges.

Almost every fine feather exhibits a sort of iridescence if we look through it towards the light. The system of fine lines is then represented by the series of radii or barbules on either side of the rami or barbs. That these parts are minute enough for this is proved by observation. We know that "Gitterfarben" begin to be visible to the naked eye if there are about twenty interstices to a millimetre. Now in a feather taken from the neck of *Pitta* (in the green part of the feather figured), I found the distance between the top of the two neighbouring barbules equal to 0·05 mm., or at another part = 0·04 mm.

Explanation of the Objective structural Colours,

i.e. colours which are due to a particular structure of the feather-substance, which contain a pigment differently coloured from the colour actually observed, and which are not variable.

Blue feathers.—All attempts made by chemists to find a blue or a violet pigment in feathers have been unsuccessful. Such feathers contain only a black-brown to yellow pigment. The simplest proof of this astonishing fact is that such feathers, if examined with transmitted light under the microscope, appear invariably brown. The blue feathers of Parrots lose this colour if held against the light, *i.e.* if examined under indirect light.

Moreover, we can make a crucial test. If certain colours result from a particular surface-structure of the feathers, these colours must disappear if we destroy the supposed colour-producing parts. This can actually be done. If we press one of the deep-blue feathers of a Maccaw between two hard planes, so as to squash or smash the stratum of prismatic cones, or if we hammer it carefully, the blue immediately disappears, and the injured part looks grey or brownish according to the underlying pigment. The same is the case with the beautifully blue feathers of *Artamia*. Green parrot-feathers, when treated in a similar way, become yellow, since this is the colour of their pigment. Thus structural or optical colour may, so to speak, be knocked out of a feather. (Fatio observed that blue disappears after injuring the surface by scratching off some of the enamel.) This explains the dark appearance of the abraded parts of feathers of Parrots and other vividly coloured birds. Again, red, orange, brown, black, and most of the yellow feathers (*i. e.* such which owe their colour directly to pigment) do not lose or change their colour under any physical treatment.

The explanation of the *blue* colour is the most difficult of all in those feathers where the blue is independent of the position of the eye, *i. e.* in which the blue does not change. In most cases the blue is confined to the rami, which, for instance in *Cœreba* and in *Artamia*, in the blue parts of the feather are devoid of cilia and radii, and are broader and flattened out (*cf.* Fatio).

With a magnifying-power of about 640, we first observe that the whole ramus is covered by a transparent, slightly yellowish, or perhaps quite colourless, sheath or coating, the thickness of which is not more than 0·0014 of a millimetre. The surface of this sheath is uneven and granulated. Immediately under this sheath we find one continuous layer of prismatic polygonal (frequently hexagonal) cells or cones. Most of these cones are broadest at their apices, and become smaller towards their bases; others have nearly parallel walls or may be broadest below. (This layer of cones has been called by Fatio, its discoverer, "émail.") The space between their apices seems to be filled up with the same matter as the coating. The colour of the cones is pale yellowish, or, if this is only the reflection of the underlying pigment, they are colourless. The distance between the middle of two neighbouring apices I found equal to 0·0050 of a millimetre; this would also be their breadth at the base. Their height seems to be slightly larger. No actual measurement, however, could be obtained, as I did not succeed in getting a clear side view of them. As to the structure of these little cones themselves, it is very difficult to arrive at a satisfactory conclusion, considering the minuteness of the subject. However, in *Pitta moluccensis* and in *Artamia* I observed a system of extremely fine lines running parallel with the long axis of the cones, *i. e.* transverse or vertical to the long axis or surface of the ramus. These lines themselves do not seem to be straight, but irregularly waved. The breadth of each bar I calculated to be less than 0·0006 of a millimetre.

Below this stratum of polygonal prisms or cones lies brownish-yellow pigment, near the middle of the barb; where the layer of pigment is thicker it looks black-brown. This pigment, of course, together with the proper substance of the feather, occupies the rest of the barb. Thus we have, if proceeding from the surface to the middle of a blue barb; the following structure (fig. 1):—

1. A transparent, apparently homogeneous sheath of ceratinine (S S).

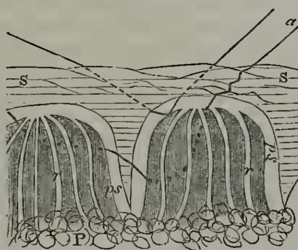
2. One layer of prismatic cells; and 3, under this, a brownish pigment (P).

The sheath may vary in thickness and in surface-structure from about 0·0014 to 0·0043 mm.

In *Pitta* I calculated its thickness to 0·0016 mm., and the surface appeared to be quite smooth; whilst in *Cœreba* each top of a cone corresponded with a slight elevation of the sheath.

The breadth, or diameter, was calculated to about 0·006 mm.; it agrees very closely with that of *Cœreba* and *Ara*.

Fig. 1.



Diagrammatic section through part of a barb of a blue feather.

Fatio, who examined the structure of blue feathers, also says that under the prismatic layer there are "de grandes cellules polygonales à noyau coloré." But I suppose that this is an optical delusion, and that the large polygones (generally hexagones) which we see while looking vertically down upon the surface of the rami are the lateral outlines of the prismatic columns. Therefore what he figured (*op. cit.* plate iii. fig. 6) as polygones are simply the foreshortened columns, and the underlying pigment gives them the appearance of cells with a dark nucleus.

The thickness of the surface-coating of blue feathers varies considerably in different birds, and even in different feathers of the same bird. Differences between 0·0016 and 0·0043 cannot be put down as mistakes of measurement. Again, we know that the thickness of colour-producing plates varies from about 0·00006 to 0·0004 mm., giving bluish-white or pale orange light respectively. And if the plates in question are thicker than about 0·0005 mm., they cease to produce colour, and the law of colours of thin plates is not applicable to them. Now our surface-coating of 0·004 is about ten times thicker than the thickest of colour-producing plates; consequently this surface-coating cannot be the cause of the blue colour. Moreover, we find quite a similar sheath surrounding red and black feathers; and therefore the function of this sheath will be, besides merely protecting the feather, to give the blue colour, produced by other parts, a glossy brilliant appearance. This, however, does not mean that this transparent sheath is superfluous or unimportant to the appearance of blue; since, supposing the blue is produced by the underlying cone-stratum, there must be some material to reflect this blue to our eye, in a similar way that a piece of wood shows its colour up much better when polished or varnished.

We must therefore look for other reasons for the appearance of blue. It is true that all blue feathers contain a yellowish to brown pigment; but the same is the case with many others, like yellow and green feathers, and, besides this, a yellow pigment alone can never produce blue.

The most essential part of blue feathers is the layer of prismatic columns; but as these vary considerably in size, from 0·011 to 0·003, they alone cannot be the essential part, nor can it be the thickness of the transparent coat of the little columns themselves, since even this extremely thin coating is sometimes too thick to allow the application of "thin-plate colours."

As the primary cause, we have to consider the fine ridges which we observe on the outer surface of all these prismatic columns. Many of them are so fine that they are even narrower than the length of one wave of light (the length of one wave of red light being 0·0007, that of violet being 0·0004 mm.). As they form a system of ridges, I am inclined to apply to them the theory of "Gitterfarben," and I explain the blue colour of feathers by this theory.

The colour produced by thin plates depends entirely on the proportion of the thickness of the plate to the length of the waves (w); consequently if this proportion is equal to x, and y is the thickness of the plate when first looking red, this same colour will appear every time when the thickness (y') of the plate has increased to an odd multiple of wx. But after a certain thickness is obtained, the plate loses the power of producing colour. Very similar conditions apply to the theory of colours produced by a system of narrow ridges. However as these ridges in the cones are so minute that a cipher generally does not appear before the fourth decimal, we are unable to measure them with exactness. Moreover these ridges do not appear always as straight lines, but seem to be waved; to measure the length and deviations of these waves would be mere guesswork.

Whether this system of ridges is the only cause of the blue colour is doubtful; very likely the transparent coating and the cones themselves will considerably influence the light passing through them. The production of blue therefore in a feather would be the result of a very complicated process.

Let us throw only a furtive glance at some of the changes which the light falling upon and passing through a blue feather is likely to undergo. First, part of the rays will be simply reflected from the outer surface of S S (fig. 1, p. 413); secondly, the rest, before passing through this stratum, will be variously broken and reflected *before* reaching the coating *ps*, since the stratum SS is not homogeneous, but consists apparently of several irregular scales and secondary strata; thirdly, the coating, *ps*, breaks the rays again and partly reflects them, and, if it is only 0·0006 mm. thick, as in *Pitta*, it is thin enough to allow the application of the theory of thin-plate colours; fourthly, the system of ridges; fifthly, some rays will reach the layer of brownish pigment. How much of them is absorbed, how much reflected as brownish light, and what the changes are of this brown light before it comes up again to the surface, we cannot tell. Again, the ray *a* will be under different conditions to the ray *c*. To follow and to calculate all these changes would be almost a superhuman task. We know only the result, namely blue colour.

By the application of the theory of colours of narrow ridges we are enabled to explain several other colours, fortunately under less difficult circumstances. We have seen before that many yellow feathers owe their colour to a yellow pigment. But several of them do not contain any pigment. The thin rami and radii of the downy part of a feather of *Pitta*, for instance, appear coloured (yellow) only under direct light, but they are colourless if examined under the microscope with transmitted light. Now in yellow feathers, no matter if they contain pigment or not, the surface shows very fine longitudinal ridges, which are more or less parallel to one another, and which appear as straight lines. This I found was the case in the yellow feathers of *Pitta, Psittacula, Arachnothera, Picus*, and *Parus*. The distance between the top of two neighbouring ridges varied from 0·001 to 0·0005 of a millimetre. That there are real ridges on the surface we can see on a transverse section of a yellow radius. The radius of a yellow pectoral tuft-feather of *Arachnothera* (Plate XXVIII. fig. 6) had a diameter of 0·007 mm.; as there were about twelve such ridges, like α, β, γ, their distance could not be greater than $\frac{0{\cdot}007}{12} \cdot \pi = 0{\cdot}0018$ mm. In *Pitta* the radius of a half-downy feather had a diameter of 0·012 mm. All round there were about twelve ridges, and the breadth of one ridge was rather smaller than the interstices; therefore the breadth of one ridge must be smaller than $\frac{12{\cdot}0}{12+12} \cdot \pi = 0{\cdot}0015$ mm. Another method of calculating gave 0·0012 as the breadth of one ridge.

Violet feathers.—Similar ridges exist on the surface-coating of violet metallic feathers, as, for instance, in *Æthopyga* and in *Sturnus*; but the ridges do not appear to be quite straight, moreover they are much finer; in *Sturnus* only 0·00085 mm.

Green feathers.—Only in the Musophagidæ green pigment has been found. All other green feathers contain only either zoofulvin or a black-brown pigment. Krukenberg suggested therefore that the green appearance is the result of a mixture of the yellow-pigment colour and of a blue optical structural colour. However, this cannot well be always the case, since most green feathers do not show that peculiar structure which we invariably meet with in blue feathers.

All the green feathers which I have examined show the following structure:—Generally a transparent smoothly surfaced sheath surrounds the rami and the radii, which are both green. Between this sheath and the invariably present yellowish, brownish, or pinkish pigment one sees a system of ridges and fine pits. These ridges are shorter and less regular than those observed in yellow feathers, and the little pits are rather irregularly dispersed over the shaft and plane of the barbs and barbules. The more regular and parallel these furrows are, the more approaches the green colour to a yellowish tinge. As we know of no green feathers without any pigment, and always with such an irregularly ridged and furrowed surface-structure, we cannot say that this structure directly produces green, nor that it produces blue. We must accept that they break the yellow light, issued from the yellow pigment, into green.

Red feathers are frequently surrounded with a thick transparent sheath, for instance those of *Rhamphastus*; but they have no peculiar or particular surface-structure, and the large wrinkles which we observe in them seem to be merely the result of a drying-up process of the horny feather-substance. In orange or orange-brown feathers, however, we frequently find a dark red pigment and yellow surface-structure.

Explanation of subjective or metallic colours.—We speak of metallic colours if the feathers under reflected light appear with a metallic gloss, and if their glossy colour changes into another one according to the position of our eye. If we look in a direction nearly parallel to the plane of the feather it will appear black. This can be done in two ways (fig. 3, p. 420): first, with our eye between the object and the light, a position which I propose to call A; secondly, with the object between the light and the eye, position C. By passing the eye from A to C, along the line indicated by the arrow, we notice the gradual appearance of all the various metallic colours which the feather is able to display. We further observe that these colours do not appear at random, but, and this is of the greatest importance, that they begin with the colours nearest to the red side of the spectrum, and end with the violet. The position just intermediate between A and C is that in which we look vertically down upon the plane of the feather, with the object turned fully to the light; no matter, however, whether this position is produced by looking at the feather in the way as indicated by diagram B or D. This position we call B.

In order to ascertain this fact, I have examined, under these three positions, about eighty birds of all orders, wherever metallic colours were present, and I did not find one single exception to the rule. With the exception of two particular cases, which I shall explain later on, the metallic parts of all these birds look perfectly black in position A; if we turn the bird to position B it will, let us say, look green; and halfway between B and C this bird will assume a blue colour, which again passes into violet before appearing black again in position C. If the bird begins with bronzy red, it will change through golden green to pure green, then through bluish green to blue and violet. There is not a single feather which, if moved from B to A, changes from green to blue, in other words from the violet to the red end of the spectrum. Thus we are able to predict into which colour a bird can change if we know its colour in position B. Thus a blue feather can only become purple or violet; a green one has more changes, and a golden-green one still more. It is, however, very rare that a feather changes through more than half of the spectrum; a coppery-red feather will generally cease with green; a violet feather cannot change at all, except into black, since beyond the violet there are no visible colours in the spectrum.

Another important fact is that metallic feathers can appear in any colour which is represented in the spectrum, but not in any which, like brown or grey, are not spectral colours. All these circumstances induce me to explain the changeable metallic colours as prismatic; and in order to prove this we have to examine the feathers for their prismatic structure. In any metallic feather the metallic colour is confined to the radii which are entirely devoid of ciliæ, and consist of a series of variously shaped compartments which overlap one another like tiles of a roof.

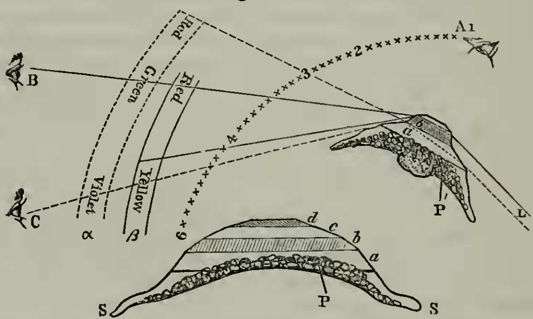
Fig. 1, Plate XXVIII., represents a barbule of a violet feather of *Æthopyga*; it consists of about fifteen compartments, each 0·03 mm. long and 0·03 mm. broad, and each forming a plane. Fig. 9 *a*, Plate XXVII., shows part of a barbule of *Nectarinia famosa*, brilliant green in position B, blue in C, black in A; each compartment was 0·027 mm. long and 0·015 mm. broad. If turned on the edge and looked upon sideways, they look like fig. 9 *b*; each compartment is convex-concave, with the convex side lying uppermost turned towards the light. In Jacamar, coppery red in positions B and A, green in C, they measure 0·040 by 0·018 mm. Every one of these compartments is surrounded by a transparent horny coat, the thickness of which varies from 0·00085 mm. (*Sturnus*) and 0·0015 mm. (Jacamar), 0·0012 (*Æthopyga*) to 0·0022 mm. (*Galbula tombacea*). The surface of this coat is either perfectly smooth and polished, like in *Nectarinia famosa*, or, in violet feathers, contains very fine longitudinal ridges, or, as in Jacamar, it showed very fine and numerous little dots. Below this transparent and apparently colourless sheath lies brownish to black pigment evenly dispersed.

Now, then, let us take a transverse section of such an arrangement (S S being the transparent sheath, P the pigment), and put it in a position that the light falls upon it from L (fig. 2, p. 418). A very small part of the orbit of a circle or any curve may be treated as a straight line; we thus may regard this sheath as consisting of a number of small prisms. We know that a prism in such a position, with the top or one edge directed upwards, breaks the light in such a way as to produce a spectrum on the side furthest from the light, with the red lying at r (*i. e.* towards the upright edge of the prism), and with the violet at v.

No rays, or at least no visible ones, are thrown out into the space between 1 and 2; consequently with our eye at 1, corresponding to position A, we shall perceive black. At 3 the first red rays will become visible, at 4 the blue ones, and so forth, till at 6 we come across the ultra-violet rays, where we see again black, corresponding with position C. Between 1 and 6 will be a place from where we can look at the object under full light (position B); and this, of course, is the way in which we generally describe an object.

As this agrees with observation, *i. e.* as every metallic feather (if examined in the way explained above) shows precisely the same phenomena as a prism under similar circumstances would show, we have every right to consider the explanation of "metallic varying colours" as proved. There are, however, several *observed facts*

Fig. 2.



Diagrammatic section through the barb of a "metallic" feather.

which need an explanation, since they seem rather to upset this theory.

First, why does not every metallic feather display all the colours of the spectrum? and why do they generally range not over more than a few neighbouring colours? Of course any prism, however small it be, displays all the colours of the spectrum; but this does not mean that all of them *reach* our eye! Part of the spectrum might be hidden by some other object standing between it and our eye; for instance we can easily cut off either end of a spectrum by a screen. In the feathers the screen would be represented by a neighbouring radius, so that, as, for instance, in fig. 2, the lower half of the spectrum β may be concealed, in which case that feather would only vary between red and greenish. *Or* two neighbouring prisms, even if they belong to the same radius or barbule, may be so situated that their spectra partly overlap one another. This would have a double result: first, that where two complimentary colours fall upon each other they would simply produce white light; secondly, that through the combination of two different colours, as, for instance, yellow and blue, there would appear a third one, in this instance green. Thus, spectrum α, produced by the prism a, is partly covered by the spectrum β, produced by prism b; the blue of β covers the yellow of α. Now as red and green give white, and blue and yellow give green, we should in this case probably see only the colours red and orange, produced by prism a.

Another circumstance, which might make this process very complicated, is implied in the consideration that the surface of the prismatic sheath is frequently uneven. How many different systems of prisms result from this arrangement, and how in the purple feathers of an *Æthopyga* the rays of light become broken by the surface-ridges into blue and violet, we are unable to explain.

A third phenomenon, which needs explanation, is that some of the most gorgeously metallic feathers cannot be made to look black in position A or C. An example of this is the beautiful coppery-red to deep blue of a Jacamar. Under the microscope the compartments of the radii of such a feather are extremely convex, as in fig. 5, Plate XXVIII.; consequently there will be always some part of such a compartment which presents a vertical plane to the eye, and which therefore is always more or less in position B.

Now to sum up. We have to distinguish between several categories of colours in feathers.

1. *Objective chemical colours* directly produced by pigment. To these belong *black, brown, red, orange,* and *yellow*.

2. *Objective structural colours.* The feather may contain no pigment at all, and the colour be produced solely by a special structural arrangement of the feather-substance, for instance *white*, and frequently *yellow*; the latter if the surface is composed of very fine and narrow longitudinal ridges. *Or* the feather contains a yellow to brownish-black pigment, and the colour actually observed, as *green, blue,* and *violet*, is produced by a specially produced and particularly constructed transparent layer between the pigment and the surface. Of non-changing colours *blue* and *violet* are always structurally objective. *Green* seems to be only in a few cases the result of yellow pigment combined with blue surface-structure. In most cases it seems to be not a mixture of two colours, but due to yellow-pigment light being broken into green. A green pigment seems to be very exceptional.

3. *Colours which change and which entirely depend on the position of the light and eye.* They are produced by a transparent sheath, which acts like a prism. Any changing colour represented in the solar spectrum may be thus produced in feathers.

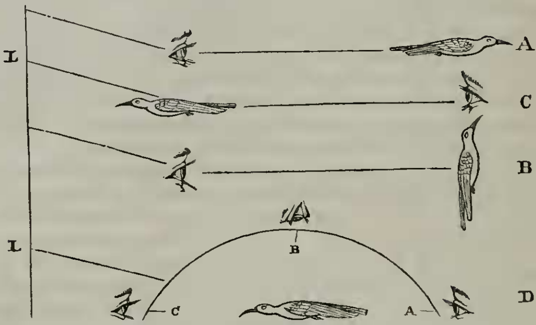
The facts which I have laid down in this communication indicate the desirability, nay even the absolute necessity, of a standard method, not only of describing but also of drawing birds and other animals which show metallic colours. These three standard positions, I venture to submit, should be the following:—

Position A, in which the eye is placed between the bird and the light, the eye and light almost in a level with the planes to be examined.

Position B, in which the bird is placed vertically to the eye, a position in which objects are usually described.

Position C, in which the bird is held in the same level with, but between the eye and light.

Fig. 3.



The three positions in which metallic colours should be observed.

EXPLANATION OF THE PLATES.

Plate XXVII.

Fig. 1. Part of a belly-feather of *Pitta moluccensis*. *s*, scapus or shaft; *r*, ramus or barb; *ρ*, radius or barbule.

2. The blue part of the ramus at * (fig. 1), as seen under the microscope with transmitted light.
3. The same, but magnified 640 times. *st*, transparent surface-coating or sheath; *c*, the layer of cones, with their sheath (*s*) and with the fine ridges (*r*).
4. The same of *Cœreba*.
5. Yellow radius of *Pitta*. *pp*, pigment-corpuscles, the shaft of the radius showing the longitudinal ridges.

6 *a*. Part of another yellow radius of *Pitta*. No pigment present.

6 *b*. Transverse section through 6 *a* at *.

7. Yellow radius of *Picus*.
8. Part of a metallic golden-green to blue feather of *Nectarinia famosa*. *s*, shaft; *ρ*, radius; *r*, ramus.

9 *a*. Distal half of one radius of *Nectarinia*, showing the transparent sheath which surrounds the compartments.

9 *b*. The same, but seen from the edge.

10. End of a metallic radius of a Jacamar. *cc*, the suppressed ciliæ.
11. Part of a metallic violet barbule of *Sturnus vulgaris*.
12. Part of a barbule of a red non-metallic feather of *Nectarinia*.

Plate XXVIII.

Fig. 1. One metallic violet barbule of *Æthopyga*.

2. One barbule of a green feather of *Palæornis*.
3. Barbule of a yellow crest-feather of *Parus sultaneus*.
4. Part of a colourless barbule of *Parus sultaneus*.
5. One barbule (radius) of a metallic (coppery-red to bluish) feather of a Jacamar. *c*, one of the compartments separated from the others, and showing its highly convex-concave shape; *r*, barb or radius.

Fig. 6. Part of a radius of a yellow pectoral tuft-feather of *Arachnothera magna*.
7. A feather of the breast of *Psittacula*, natural size.
8 *a*. Part of a barbule of the red part in the feather of *Psittacula*.
8 *b*. " " yellow " "
8 *c*. " " green " "

May 16, 1882.

Osbert Salvin, Esq., F.R.S., Vice-President, in the Chair.

The following report on the additions to the Society's Menagerie during the month of April 1882 was read by the Secretary:—

The total number of registered additions to the Society's Menagerie during the month of April 1882 was 124, of which 32 were by presentation, 65 by purchase, 18 by birth, 3 in exchange, and 6 were received on deposit. The total number of departures during the same period, by death and removals, was 82.

The most noticeable additions during the month were the following birds, all of species new to the Society's Collection.

1. A Rifle-bird (*Ptilorhis paradisea*), purchased April 4. This is a male bird in immature and worn plumage, changing very slowly into the adult dress, but apparently in good health.

2. A pair of Black-headed Tragopans (*Ceriornis melanocephala*), imported from Calcutta, and received April 5. This is the first pair of this fine species that has reached us, although I believe that several examples of it have been previously received in Europe, and there is said to have been a single example of it many years ago in the Gardens.

3. Four Rüppell's Parrots (*Pœocephalus rueppelli*) from Western Africa, purchased April 15. This species was first described and figured by G. R. Gray in the Society's 'Proceedings' for 1848 (p. 125, Aves, t. 5). Two of our specimens resemble the figure there given; the others have the rump and under tail-coverts blue.

4. A Western Black Cockatoo (*Calyptorhynchus naso*, Gould, B. Austr. v. t. 9), conspicuously differing from the Eastern *C. banksi*, of which we have also examples, in its smaller size.

5. A male Cabot's Tragopan (*Ceriornis caboti*), purchased April 18, making a fine addition to the Gallinaceous series.

6. Two of the recently described Green-horned Parrakeet, *Nymphicus uvæensis*, Layard (*suprà*, p. 480, Plate XXVI.), which we believe to be a pair, purchased April 27. These have been placed in the Parrot-house, next to our two living examples of *Nymphicus cornutus* (*cf.* P. Z. S. 1879, p. 550, pl. xliv.), and afford a fine opportunity for the comparison of these two closely allied species.

A mounted specimen of the Dusky Petrel, *Puffinus obscurus* (Gm.), which had been picked up dead in Norfolk in 1858, was placed on the table, having been sent up for exhibition by Mr. Henry Stevenson of Norwich; and the following remarks by him were read:—

"The bird now exhibited was picked up dead by a gamekeeper on the Earsham estate (near Bungay) in Norfolk, about the 10th or 12th of April, 1858, and was recorded by myself in the 'Zoologist' for that year, p. 6096. It was brought in a perfectly fresh state to a Norwich bird-stuffer, named Sayer, by Captain Meacle, who, at that time, rented the Hall and the shooting at Earsham; but as, shortly after, Capt. Meacle broke up his establishment there and left the country, this specimen was altogether lost sight of, and I was unable to confirm my first impression as to the species. Early in the present year, Mr. J. H. Gurney, Junr., and I, in comparing notes for a revised 'List of the Birds of Norfolk,' had some correspondence respecting this almost forgotten specimen, which was fortunately discovered to have been preserved at Earsham Hall, along with other birds killed on the estate, and had never been, as at first supposed, the property of Capt. Meacle. This most interesting bird has been kindly entrusted to me for further identification as to the species, and for exhibition, by Mr. W. Hartcup, of Bungay, Trustee of the late Sir W. Dalling's estate at Earsham. Owing to my temporary absence from Norwich at the time, I did not see the Petrel in the flesh, but I examined it a few days after it had been 'set up.' It had evidently not been shot; but a wound on one side of the head, as though it had been hit, or had flown violently against something, was probably the cause of its death.

"Except on the side of the head as stated, the feathers were perfectly clean and unruffled; but the inner web of one foot was partially nibbled away, as though a mouse or other vermin had been at it, at least so it struck me at the time; but I have since found the webs of the feet in other sea-birds, skins especially, slit up, from quite different causes. The injury to the head is still visible in this specimen, on the side next the back of the case, and helps to identify the bird as the one seen by me in 1858 if there could be the slightest question as to this being the same I recorded in the 'Zoologist.' The webs of both feet are now imperfect, apparently injured by insects. The man who stuffed it assured me that the Petrel was a *male* by dissection, and in poor condition.

"I have recently taken the following measurements:—

	inches.
Total length	12 (scant).
Beak	1
Carpal joint to end of longest primary	$7\frac{3}{16}$
Tarsus	$1\frac{7}{16}$ ($1\frac{1}{2}$ scant).
Middle toe and claw	$1\frac{5}{8}$

"N.B. When I first saw it, having been dead some few days, the beak was a dull black and the webs of the feet yellowish brown."

The following papers were read:—